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**PACKAGE SEWAGE TREATMENT PLANTS
CRITERIA DEVELOPMENT. PART II:
CONTACT STABILIZATION**

Robert M. Brown, et al

**National Sanitation Foundation
Ann Arbor, Michigan**

June 1968

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PACKAGE SEWAGE TREATMENT PLANT CRITERIA DEVELOPMENT
PART II: CONTACT STABILIZATION

NATIONAL SANITATION FOUNDATION
ANN ARBOR, MICHIGAN

Robert M. Brown, President
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FEDERAL WATER POLLUTION CONTROL ADMINISTRATION
DEMONSTRATION GRANT PROJECT

WPD-74

ANDREW T. DEMPSTER, Project Director

June 1968

I

TABLE OF CONTENTS

	Page		Page
Project History	3	General Test Conditions and Reporting	14
Contact Stabilization Definition	3	Startup Performance Evaluation	16
Description of the Contact Stabilization Process	5	Variable Flow Pattern Performance Evaluation	17
Startup and Solids Accumulation	8	Deviations From Standard Methods	17
BOD Removal	10	Flow Patterns	18
Oxygen Requirements	10	Responsibilities	18
Nitrification	10	The Manufacturer-Supplier	18
Solids Separation	10	The Buyer-Owner	19
Skimming	11	The Consulting-Supervising Engineer	19
Temperatures	11	The Installer-Contractor	20
Mixed Liquor and Stabilization Compartment Solids	11	The Regulatory Agency-Official	20
Solids Wasting	11	The Plant Operator	20
Check List for Routine Maintenance and Operation of Contact Stabilization Package Sewage Treatment Plants	13	The Performance Evaluation Organization	20
Performance Criteria and the Standard Performance Evaluation Method	14	Discussion	21
Prequalification	14	Acknowledgments	21
		References	20

TABLES AND FIGURES

Figures		Page	Tables		Page
1	Contact Stabilization Process Flow Diagram	4	I	Performance of Contact Stabilization Plants	12
2	Flow Pattern	5	II	Steady State Data, Fall and Winter Studies	24
3	Research Site and Staff Photographs ..	6	III	Steady State Data, Spring and Summer Studies	25
4	Four Contact Stabilization Sewage Treatment Plant Photographs	7	IV	Variable Flow Pattern, Winter and Spring Studies	26
5	Relationship Between Suspended Solids in Contact and Stabilization Compartments and Return Sludge Rates	9	V	Variable Flow Pattern, Spring and Summer Studies	27

PACKAGE PLANT CRITERIA DEVELOPMENT

PART II: CONTACT STABILIZATION

I. GENERAL

The need for some form of treatment and disposal of wastes has been one of mankind's pressing problems since early times. With the amount of effort and thought which has been applied to this problem, it would seem that he should be further along in finding its solution. Unfortunately, however, increased population and successive changes in the environment have added to the variables, and the problem has become more difficult to solve. In the beginning, waste disposal methods were primarily accidental, and treatment was limited to natural physical, chemical, and biochemical reactions. When wastes were discharged to receiving streams, the problem was simply moved to other populated areas downstream, creating a threat to water supplies. As a result of efforts to remedy this new threat, additional treatment methods, including gravity separation, chemical coagulation, aerobic biological oxidation, and incineration, were developed. Alone, or in combination, these methods are the basic ones being used today to remove objectionable fractions from wastewater before it is discharged to a nearby watercourse.

As stated in Part I of the National Sanitation Foundation Report: "Package Sewage Plant Criteria Development,"¹ man's present state of mobility has led to the development of suburbia. In their early stages of existence, suburban communities may not have access to the inner city's system for collecting and treating wastes. In addition, the septic tanks, cesspools, or privies used in rural areas are not suitable for the disposal of wastes in these more densely populated suburban developments. Package sewage treatment plants, which offer a relatively high level of treatment, have been designed to meet the needs for waste treatment in these areas.

In 1947, an underloaded "package" activated sludge plant at East Palestine, Ohio,² was attracting attention. All of the activated sludge was being recirculated through the aeration tanks from the final settling tanks, with no wasting of excess sludge. An equipment company became interested in this process modification and developed the extended aeration type package plant. Almost simultaneously, Ullrich and Smith³ were developing new operational procedures which

would permit a conventional activated sludge plant in Austin, Texas, to treat larger flows and greater loads. A 15-20 GPM pilot plant utilizing the "Biosorption Process" was constructed in 1950. This was essentially the same process which is now commonly referred to as "Contact Stabilization."

Ullrich and Smith described their modification of the conventional activated sludge process in the following distinct treatment steps:

1. Activated sludge is brought into intimate contact with raw sewage. Brief mixing of the two is accomplished either mechanically or with air. The activated sludge adsorbs and absorbs a very high percentage of both the suspended solids and dissolved pollutorial material.

2. After the brief mixing, the mixed liquor flows to a clarifier where it is settled. The effluent is clear, low in BOD and low in suspended solids. This is the plant effluent ready for final disposal.

3. The sludge from the clarifier which now contains the original activated sludge plus the adsorbed and absorbed suspended and dissolved pollutorial matter from the raw sewage is conducted to an aeration compartment, where it is aerobically digested in preparation for recycling. In other words, the sludge from the clarifier is reactivated by means of aeration so it can again be used in the mixing compartment for removing polluting materials thus making the process continuous."

The pilot plant studies demonstrated that the "Biosorption" (contact stabilization) process was practical. The Austin plant⁴ was expanded by converting a primary clarifier to a final clarifier and by adding two more final clarifiers, two additional blowers, a grit removal unit and bar screen, and auxiliary pumping equipment. Without adding any new aeration tank capacity to the original 6 MGD activated sludge plant, the capacity of this plant operating as a "Biosorption" unit increased to a 16.0 MGD average flow. The plant was reported to be "most satisfactory"

PROJECT HISTORY

In 1957, at a meeting of public health sanitarians, sanitary engineers, manufacturers of package sewage treatment plants and users of these plants, it was suggested by the Sewerage Committee of the Engineering Section of the Michigan Public Health Association that methods for evaluating the performance of package sewage treatment plants should be established. It was proposed that some independent agency such as the National Sanitation Foundation undertake a study of these plants. No means of financing the study were found, however, so the project did not go forward at that time.

In 1961, The Great Lakes Upper Mississippi Board of State Sanitary Engineers requested its Sewage Works Standards Committee to investigate ways of developing performance evaluation criteria for package treatment plants. In 1962, the committee recommended to the Board that the committee chairman be permitted to explore, with the National Sanitation Foundation, the possibility of the Foundation's undertaking such a study. A resolution adopted by the Board recommending that the National Sanitation Foundation consider taking such action was responsible for the creation of a Joint Industry-Public Health Committee, which developed: (1) a methodology for the study, and (2) an application for a U.S. Public Health Service Demonstration Project Grant to provide the necessary financial support. Other organizations, including the Conference of State Sanitary Engineers and the Association of State and Interstate Water Pollution Control Administrators added their support. In 1964, the project was approved by the Demonstration Grants Committee of the U.S. Public Health Service and designated as Demonstration Grant Project WPD-74, with a starting date of January 1, 1965. Sponsorship was transferred to the Federal Water Pollution Control Administration in 1966. Four contact stabilization plants were loaned to the Foundation by their respective manufacturers for use in this phase of the study.

The Joint Industry-Public Health Committee held its final meeting on January 15, 1965. At that meeting, the Package Sewage Treatment Plant Criteria Development Project came into existence as an official National Sanitation Foundation study. An Executive Committee, a Policy Committee, a Technical Committee and an Industry Committee were appointed shortly thereafter. The original members of these committees are listed in the previous report.¹

The Technical Committee met in Ann Arbor on March 11 and 12, 1965. Plans for the research site facilities were presented by Mr. George E. Hubbell, of the consulting engineering firm of Hubbell, Roth and Clark, Bloomfield Hills, Michigan. Project methodology was also discussed. The committee agreed to limit the first year of the study to extended aeration type package plants, and to study other process modifications such as CS at a later date. These recommendations from the Technical Committee were approved by the Policy Committee on April 12, 1965. Bids were immediately sought, and the low bidder, Midwest Mechanical Contractors, Inc., started construction on April 28, 1965.

Details and plans for the research site facilities, located on two acres of land adjacent to the Ann Arbor Wastewater Treatment Plant at 49 South Dixboro Road, Ann Arbor, Michigan, are presented in the Extended Aeration Report.¹ Results of the EA study were first reported at the Water Pollution Control Federation Conference at Kansas City, Missouri, in October 1966. The first printing of the Extended Aeration Report¹ was released late in December of 1966.

The project staff, which the former Project Director, Mr. Brian L. Goodman, assembled during the time of construction of the research site facilities, was composed of Mr. John G. Havens (Research Site Manager), Mr. Robert S. Greathouse (Project Chemist), Mr. Wendell J. Birdsall (Research Assistant), and Mrs. Adeline W. Carter (Project Secretary). Mr. John P. Karr (Research Assistant) joined the staff early in 1966. Mr. Goodman resigned from the project in November 1966, and Mr. Greathouse resigned in January 1968. Several students were employed as research assistants during the summer and fall of 1967. Miss Nina I. McClelland and Professor Jack A. Borchardt of the University of Michigan have served as consultants to the project. The National Sanitation Foundation has indeed been fortunate in having a research staff that has demonstrated a great interest in its work and has assumed responsibility whenever necessary.

CONTACT STABILIZATION DEFINITION

The Technical Committee, in a meeting at Ann Arbor on March 21, 1968, approved the following definition of the Contact Stabilization Process:

after it had been converted to contact stabilization.

In 1951, Eckenfelder⁵ conducted a pilot plant study on the oxidation of cannery wastes by applying what is now known as the contact stabilization process, but was designated at that time as "high rate biological sludge treatment." This pilot study was conducted at the H. J. Heinz plant in Chambersburg, Pennsylvania, on tomato and apple processing wastes. Average BOD reductions of 85 percent were reported for raw wastes with average BODs of 1250 mg per liter from apple processing, and 450 mg per liter from tomato processing. The air requirements were 2.5 cu.ft. per gallon for the apple wastes, and 1 cu.ft. per gallon for the tomato wastes. Low pH values were adjusted by adding caustic. In 1952, Eckenfelder and Grich⁶ reported on the construction of a full scale plant at the same H. J. Heinz facility. This plant treated peach as well as tomato and apple processing wastes. BOD removal efficiencies of 80-90 percent were obtained with wastes from various combinations of these products.

It was logical for contact stabilization to be adopted by manufacturers of package plants. Some manufacturers designed plants which could be operated either as extended aeration or contact stabilization units, with the result that plants of the latter type could provide almost double the treatment capacity without increasing their dimensions or volumes. For purposes of simplicity, extended aeration plants may hereafter be referred to as EA and contact stabilization plants may be designated as CS.

This principle of expanding the capacities of existing conventional activated sludge plants has been utilized in other large municipal plants in this country. In addition, many small municipalities have installed new CS plants with capacities between 100,000 and 1,000,000 gallons per day. CS plants, while not always shipped as completed units, can still be classified as package plants. They are pre-engineered using standardized aeration, pumping and sludge collecting equipment, and are installed in plant structures that are field erected from prefabricated steel components, or constructed of reinforced concrete.

Relatively few references to contact stabilization are contained in the literature. In 1959, Zablatzky, Cornish, and Adams⁷ studied various process components in the laboratory. Relationships between sludge production and BOD re-

moval, and aeration time and oxygen uptake were determined. As a result of this investigation, a portion of an existing activated sludge plant at Little Ferry, New Jersey, was converted to contact stabilization. Full scale plant operation at 14 MGD indicated that the existing aeration tanks were capable of treating 56 MGD if the air supply and the dispersion units were increased sufficiently.

In Greensboro, North Carolina, textile mill wastes were treated by the CS process in a modified activated sludge plant in 1958. Jones, Alspaugh, and Stokes⁸ found that this process, when used to treat a waste composed of approximately 1/4 mill waste and 3/4 domestic sewage, removed between 85 and 90 percent of the BOD and between 80 and 85 percent of the suspended solids. These removals compared favorably with those of trickling filters and conventional activated sludge units which had previously been used to treat the same waste.

Sawyer⁹ analyzed various activated sludge modifications, including contact stabilization, step aeration, the Kraus Process, a "completely mixed system" and a high rate activated sludge process. A comparison of these processes indicated that contact stabilization had the highest BOD loading potential (144 lbs. per day per 1000 cu.ft. of aeration capacity). In conventional activated sludge plants BOD loadings are kept below 35 lbs. per day per 1000 cu.ft. of aeration capacity when good design practices are observed.

An analysis by Hazeltine¹⁰ in 1955 compared BOD loadings for a conventional activated sludge plant with those for a separate sludge reaeration or CS plant. Both plants were theoretically loaded with 35 lbs. of BOD per day per 100 lbs. of sludge solids. The sewage had a BOD of 200 mg per liter, and the flow for both plants was 24 MGD. In the conventional activated sludge plant, an aeration tank capacity of 10 MG was required for a mixed liquor solids concentration of 1370 mg per liter. The volumetric BOD loading was 30 lbs. per day per 1000 cu.ft., which is just under the limit cited by Sawyer.⁹ The CS plant with the same ratio of BOD to solids loading required two 2 MG tanks, one for reaeration solids and one for mixed liquor, and the volumetric loading was 74.5 lbs. BOD per day per 1000 cu.ft. (33.4 cu.ft. per day per lb. of BOD). Hazeltine presented these examples to illustrate the fallacy of setting up volumetric BOD loading criteria for aeration tanks without giving consideration to their solids content.

PROJECT HISTORY

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CONTACT STABILIZATION DEFINITION

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"Contact Stabilization is a form of the activated sludge process where aeration is carried out in two phases in two types of tank: the contact tank where raw sewage solids are adsorbed and absorbed on the microbio masses; and the 'stabilization' tank where the solids, which have been removed in a final settling tank, are partially stabilized by reaeration before being recombined with

the incoming raw sewage. An aerobic digestion tank may be included as a part of the process.

For the purpose of criteria development and subsequent testing of package plant units, the sludge components wasted from the process, whether or not a fraction thereof is returned to the process, will be included in the studies."

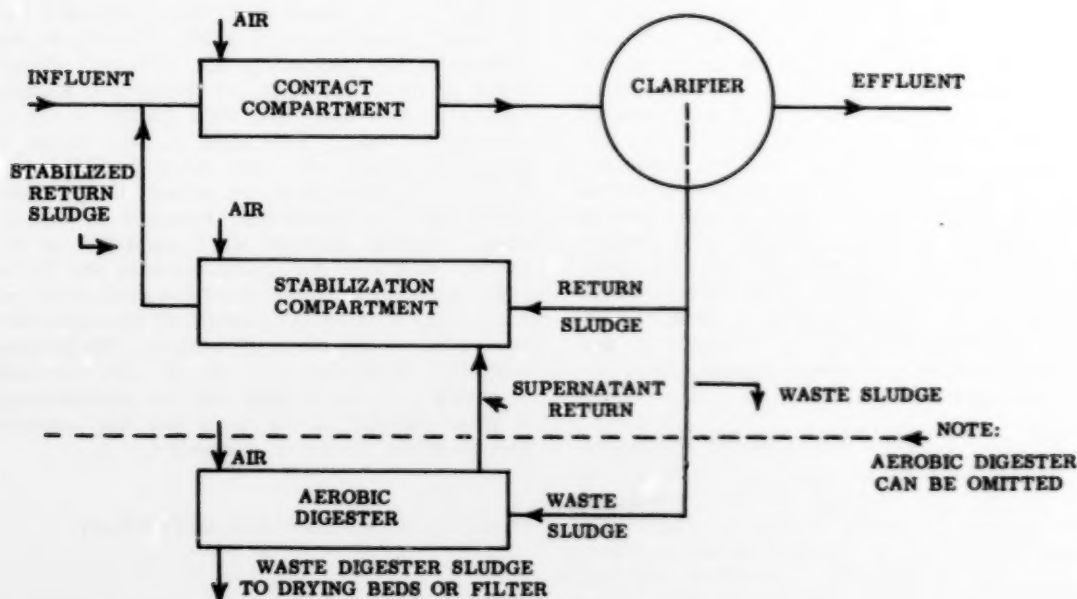
II. STUDY AND FINDINGS

GENERAL

The purpose of this project was to establish a method for evaluating the performance of package sewage treatment plants. Extended aeration package plants have been and are being used to treat sewage from suburban shopping centers, motels, schools, and other establishments that do not have access to municipal sewerage systems. Contact stabilization package plants are used for larger establishments of the types just mentioned and for small municipalities. The recent interest of the Federal Government in improving stream conditions has, no doubt, created an increased demand for package

sewage plants. Regulatory agencies throughout the country have had an interest in performance evaluation of the contact stabilization process; therefore, a criteria development project for package sewage plants should include plants of this type. A flow scheme for the contact stabilization process is shown in Figure 1.

Only four plants were available for this phase of the study. Because of their large capacities, there was an understandable reluctance on the part of manufacturers to provide the project with new CS plants. Field erection of prefabricated components is more costly than shipment of a fully assembled unit.



CONTACT STABILIZATION PROCESS FLOW DIAGRAM

Figure 1

The first plant was placed in operation in September 1966. This was a 16,000 GPD EA plant which was converted to a 30,000 GPD CS unit. The second plant, of 50,000 GPD capacity, arrived at the research site in April of 1967. This plant could also be converted to an EA plant, a feature that is quite common with these two process modifications. The last two plants were converted to CS from EA plants already located at the research site, and had capacities of 10,000 GPD and 20,000 GPD respectively. The first plant has been operated as a contact stabilization unit for approximately 15 months. The second plant was started in May 1967 and has been operated for approximately 12 months. The remaining two plants were put in service in December 1967 and have been operated for a six-month period. The three largest plants were constructed of steel and installed on a concrete pad above grade, while the smallest plant was prefabricated of concrete and installed so that two-thirds of it was below grade. The research site staff operated and maintained the plants during this latter part of the study in much the same manner as the extended aeration plants were operated and maintained. The research facilities were essentially unchanged. Two plants were located on one side of the 140 ft. long control shelter, while the other two were located on the opposite side. The flow control equipment developed for the extended aeration plants¹ was also utilized for this study. Sewage used in the operation of the plants was obtained from the 48 inch main connecting the City of Ann Arbor's sewerage system to its treatment plant, which is adjacent to the National Sanitation Foundation's research site. Raw sewage flows through a one-fourth inch slot comminutor located near the control shelter, and is then pumped through a common header to the flow control units for each plant. The flow control units not only measure the quantity of influent to each plant, but also control the hourly variations that would be expected for different patterns of flow. Flow measuring recorders and totalizers on each control unit served as a means for actuating the sampling pumps at set flow intervals for collecting samples from the effluent connections to each plant. Similar sampling equipment was also installed on the main distribution line, and the samples were composited in conformance with the particular flow pattern being used to supply the contact stabilization plants with raw waste.

Two flow patterns were used in operating the plants, steady state and the variable flow pattern. The latter pattern is illustrated by Figure 2 and is specifically defined under Sec-

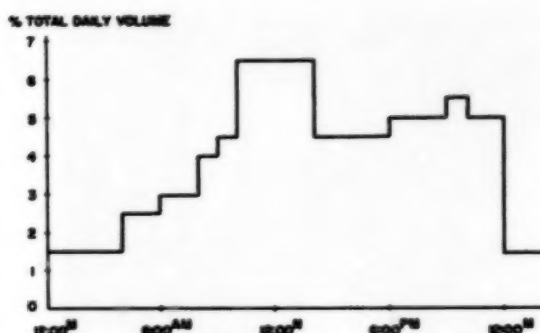


Figure 2. Variable Flow Pattern

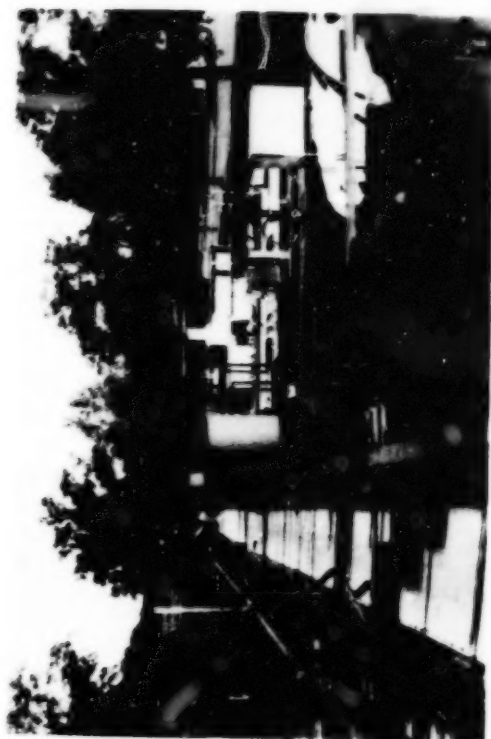
tion F, Performance Criteria. This pattern was considered to represent the normal variations in daily flow rates under a variety of circumstances. The steady state flow pattern would, as the name implies, evenly distribute the daily flow.

Samples collected by the composite samplers, and those collected from specific locations or portions of the process were analyzed in the National Sanitation Foundation Laboratory facilities. The methods prescribed in the 12th Edition of *Standard Methods*,¹⁴ unless otherwise specified, were employed in all analytical work.

Until May 1967, the laboratory was located in the control shelter. At that time, the Ann Arbor Wastewater Treatment Plant Superintendent, Mr. Richard Sayers, arranged for the Foundation staff to share the laboratory facilities in the Ann Arbor plant. The limited laboratory floor space in the control shelter, as opposed to more adequate laboratory and office space available in the Ann Arbor facility, made this move most advantageous to the operation of the project. The control shelter facilities were still used for making COD determinations, and all of the flow control and sampling equipment for the plants was maintained in the shelter. The roof of the shelter building, by virtue of its location between the two rows of package plants, provided access to the plants located above grade. Bridges were installed between the roof walkway and the top of each plant.

DESCRIPTION OF THE CONTACT STABILIZATION PROCESS

The Technical Committee adopted a definition for the contact stabilization process which appeared earlier in this report. The list of

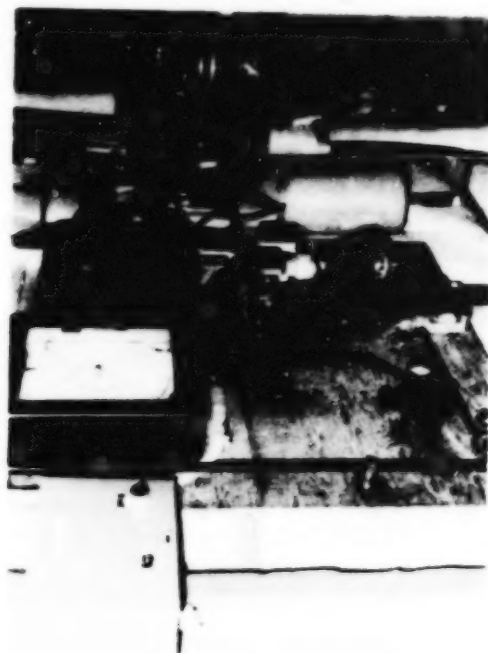


Two Views of the NSF Package Sewage Treatment Plant Research Site.

Figure 3



Research Site Staff.



Control Panel for Programming Flow and Sampling Composites.

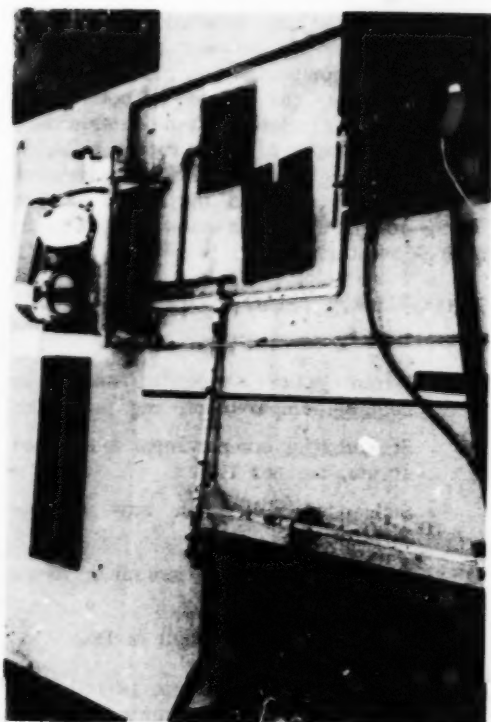
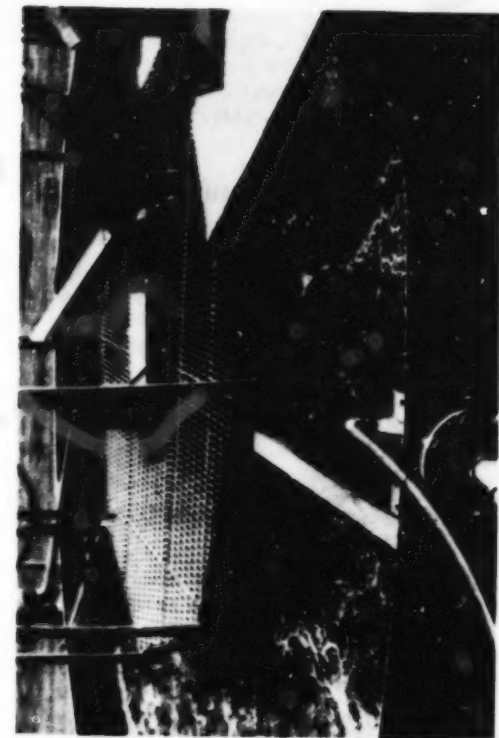
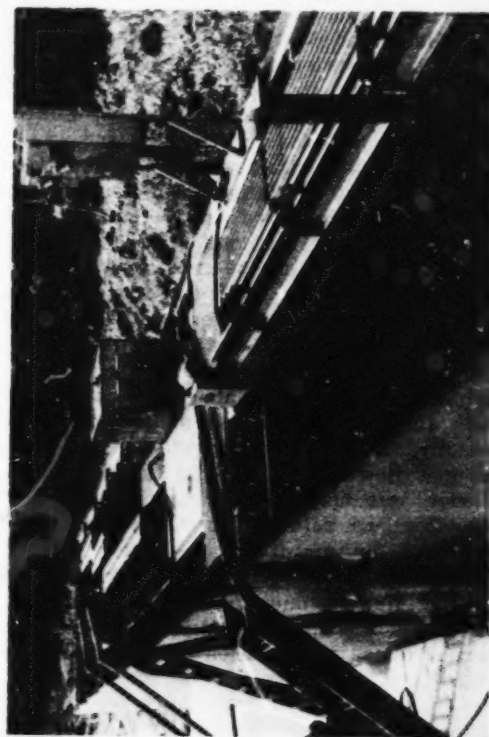
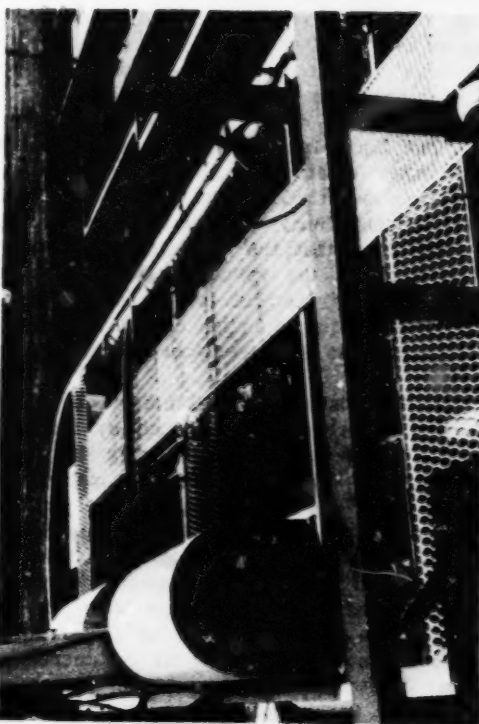


Figure 4
Four Contact Stabilization Package Sewage Treatment Plants
Utilized in Developing Performance Criteria.



essential elements of the process as described by Ullrich and Smith³ was also quoted. These are basic descriptions of the process. Each of the plants used in this study had three compartments under aeration. Raw sewage flowed into the contact aeration compartment and was mixed at the entrance with reaerated or stabilized activated sludge. The mixed liquor was kept under aeration and remained in the contact aeration compartment for one half to one and one half hours, depending on the rate of flow of the influent to the plant, and the flow of stabilized sludge into the compartment. The mixed liquor then flowed into the clarifier, where most of the organics, which were stabilized by microorganisms in the reaerated sludge and converted into flocculent particles, settled or separated readily. A relatively clear effluent of low organic content flowed over the clarifier weir. Settled sludge was collected from the bottom of the clarifier and returned to the stabilization compartment by airlift pump. After four to six hours of aeration, it was again mixed with raw sewage flowing into the contact chamber. Not all the sludge collected in the clarifier was returned to the stabilization compartment. A portion of it was diverted to the third aeration compartment, an aerobic digester, where the volume of sludge was reduced by autooxidation. If facilities were provided for separating the digested sludge from the supernatant, the latter was returned to the stabilization compartment to be combined with sludge returned from the clarifier. Periodically some sludge had to be wasted from the digester.

The liquid fraction of the inflowing sewage was under treatment only for the time that it took to flow through the contact compartment and the clarifier. Obviously, because of the shorter time that the total flow of sewage was being aerated, the volumetric capacities of the compartments used in this process were less than those required in the conventional activated sludge process or the extended aeration process.

In the contact stabilization process, BOD is rapidly adsorbed and absorbed by the biomass during the contact period. During the stabilization period, "biosorbed" organic matter is oxidized. The use of a longer contact period permits some oxidation to occur at this point, reducing the time required for oxidation in the stabilization zone for equivalent treatment. In order to increase the contact time, the return sludge rate (usually stated as a percentage of the raw sewage inflow) must be decreased, or the raw sewage influent must be decreased, or both must be decreased simultaneously. Since

the returned sludge rate controls the detention time in the stabilization compartment, it follows that this period will also be increased. The time required in either aeration compartment is also a function of the concentration of biomass in that compartment.

STARTUP AND SOLIDS ACCUMULATION

For purposes of evaluating and testing a contact stabilization package waste treatment plant, the startup period is defined as the time required after the plant has been placed in service to reach a given level of solids under aeration. It is recognized that these plants may provide an effluent of acceptable quality before this level of solids has been attained. The rate of accumulation of active solids in the CS process is a function of:

1. The suspended solids and BOD in the incoming sewage.
2. The rate at which solids are lost from the system, a factor which is closely related to clarifier efficiency.
3. The proportion of incoming inert solids that remain in the plant.
4. The rate of oxidation of solids in the process.

The return sludge rate determines the relative distribution of solids between the stabilization and the contact compartments. In the contact stabilization process, the solids in both compartments should be totaled when determining the rate of accumulation or other ratios in which solids are involved. These can be approximated if the return sludge rate and the solids content of one of the compartments is known. The basic mathematical relationship is:

$$MLSS(IFQ + RSQ) = SCSS(RSQ) + SS(IFQ) \quad (1)$$

where:

MLSS = Mixed liquor suspended solids in contact compartment, mg per liter

SCSS = Stabilization compartment suspended solids, mg per liter

SS = Suspended solids in raw sewage influent

IFQ = Influent flow rate, assumed to be unity

RSQ = Return sludge, percent of IFQ

Example: If the return sludge rate is 100 percent, IFQ = RSQ = 1. Then, assuming that the

raw sewage suspended solids concentration is 200 mg per liter and the stabilization solids concentration is 5000 mg per liter, and substituting in equation (1):

$$MLSS (1 + 1) = (1) 5000 + (1) 200 \text{ and}$$

$$MLSS = \frac{5000}{2} + \frac{200}{2} = 2600 \text{ mg per liter}$$

For a 50 percent return rate $RSQ = 0.50$ and $IFQ = 1.0$ and similar concentrations of solids:

$$MLSS (1 + 0.50) = SCSS (0.50) + SS (1)$$

$$MLSS = 5000 \left(\frac{0.50}{1.50} \right) + 200 \left(\frac{1}{1.50} \right) = 1800 \text{ mg per liter}$$

By rearranging Equation (1), the return sludge rate can be estimated if the solids content is known in both compartments.

RSQ can be calculated as a percentage as shown in the following expression:

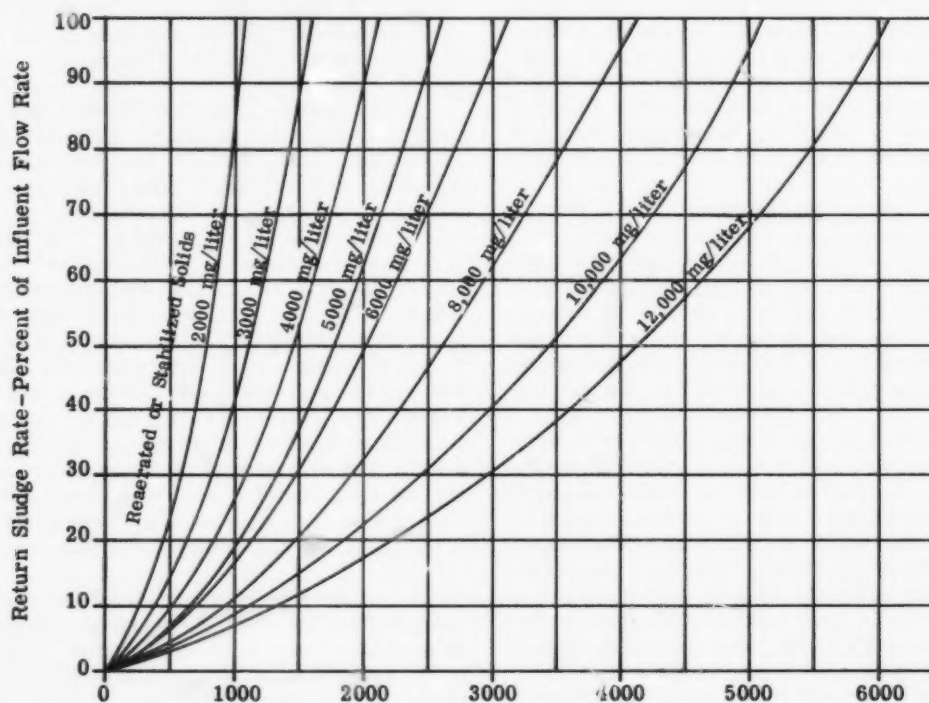
$$RSQ = \frac{MLSS - SS}{SCSS - MLSS} \quad (2)$$

Example: The return sludge rate is desired for a CS plant in which the solids concentration in the stabilization compartment is 10,000 mg per liter and the solids concentration in the contact compartment is 3000 mg per liter. The influent is assumed to average 200 mg per liter suspended solids. By substituting these values in Equation (2) the return rate can be estimated as a percentage of the rate of influent flow:

$$RSQ = \frac{3000 - 200}{10,000 - 3000} = 0.40 \text{ or } 40 \text{ percent}$$

Since solids concentrations are usually determined from grab samples, this value of the return rate should be treated only as an approximation. Solids levels in the two compartments can be determined graphically, as shown in Figure 3. CS package plants are not normally equipped with devices for measuring flows, but

Relationship Between Suspended Solids in Contact and Stabilization Compartments and Return Sludge Rates



Mixed Liquor Solids in Contact Compartment

Note: The Influent Suspended Solids Assumed to be 200 mg/liter

Figure 5

suspended solids determinations are usually made; therefore, this method of estimating return sludge rates may be helpful. For complete accuracy, time of sampling and factors which affect dilution, such as backflow, skimmer operation when skimmings are returned to an aerator, and digester overflow must be considered.

BOD REMOVAL

Mean percent BOD reductions in the four plants utilized for this phase of the study are shown in Tables II through V. The reader of this report should clearly appreciate that this data includes analytical results which were obtained in developing criteria for performance evaluation. IT DOES NOT IN ANY WAY REPRESENT STANDARDS OF PERFORMANCE TO BE ATTAINED BY PLANTS UNDER TEST.

OXYGEN REQUIREMENTS

For the complete oxidation of any given waste, the basic oxygen requirements are similar in any biooxidation process. In the first report on the Extended Aeration Process¹ a waste with certain properties was found to require 1490 cu.ft. of air per pound of BOD. When the biochemical reactions for synthesis, oxidation and autooxidation are considered, the total oxygen demand can be calculated. The Water Pollution Control Federation's Manual of Practice No. 6¹¹ gives a range of 300 to 1500 cu.ft. of air per pound of BOD for domestic wastewater.

It would appear that a change in the "treatability" characteristics of the raw waste occurred sometime during the development of these criteria. The rate of oxygen utilization decreased during this period. Although the causative agent(s) was not identified by any available physical, chemical, or biochemical means, every effort is being made to prevent its recurrence.

The plants included in this study were normally capable of maintaining a residual dissolved oxygen concentration in their aeration compartments of 1.0 mg per liter or better, except in the area of raw waste introduction. The plants all used diffused aeration. The most important factors in any aeration system are mixing and oxygen transfer. Good mixing will prevent the deposition of solids in the aeration compartments and promote adequate oxygen transfer. Periodically, as part of plant maintenance procedures, the bottom of each aeration compartment was checked with the hopper scraper to determine if deposition of sludge was taking place. The presence of such deposits could be an indication

that one or more of the diffusers is not functioning or is improperly located. Diffuser malfunction may cause a reduction in dissolved oxygen concentration in the aeration compartment. A dissolved oxygen probe can also be used to reveal diffuser problems or the lack of sufficient air flow from the compressors. Both methods were used during the study of CS plants.

NITRIFICATION

No significant reduction in nitrogen was observed in this phase of the study. Conversion of ammonia to nitrate occurred to some degree, as shown in Tables II through V. The nitrification-denitrification phenomenon¹ was not a problem in the CS units under the regime in which they were operated.

SOLIDS SEPARATION

Separation of solids by gravitational settling of suspended particles that are heavier than water is one of the basic factors in the natural purification of water courses and in water and wastewater treatment processes. The gravitational effect is defeated when the suspended solids are lighter than water, or when the upward velocity of flow in any area of the settling basin exceeds the rate of settling.

In activated sludge treatment plants and their modifications, such as extended aeration or contact stabilization, the activated sludge particles in the mixed liquor form flocs that aid in establishing a uniform rate of settling near the surface of the clarifier. At the point at which the particles decelerate to a lower settling velocity, an almost discrete solids-liquid interface forms. The zone below this interface is called the hindered settling zone, and its height above the bottom of the clarifier is affected by the concentration of solids in the mixed liquor. Below the hindered settling zone, the settling rate decreases as a result of the increasing density and viscosity of the suspension surrounding the floc, and the transition zone is formed. At some critical concentration, the solids begin to compact and the compression zone occurs.

Zone settling is represented as the initial constant settling rate of the sludge-liquid interface which occurs in a batch sedimentation test. It is a function of the initial concentration of solids and of the physical and chemical properties and flocculating characteristics of the biomass. It can be determined in the laboratory and used to calculate clarifier overflow rate limitations. The overflow rate is usually reported

in terms of gallons per sq.ft. of clarifier surface area per day. For settling to occur, the overflow rate must be less than the measured rate of zone settling.

One of the parameters which is useful in management of the treatment process is the sludge volume index (SVI). It is defined as the volume in milliliters which is occupied by one gram of mixed liquor solids after a fixed settling period, and is calculated from the following expression:

$$SVI = \frac{\text{Sett. Sol.}}{SS} \times 1000 \quad (3)$$

where:

Sett. Sol. = Volume occupied by 1 liter of mixed liquor solids after 30 min. settling time, ml

SS = Suspended solids in mixed liquor, mg per liter

Sludge density index (SDI) is the reciprocal of the SVI, times 100.

SKIMMING

The four CS plants used in this study had various forms of skimming devices for removing floatable solids. One of the plants had a mechanical skimming paddle that skimmed the floatables on the surface of a rectangular clarifier from one end to the other, where a combination skimmer and air lift transferred them to the return sludge channel. They then were mixed with the return sludge and conveyed back to the stabilization compartment, or to the aerobic digester.

Skimmers can increase the surface overflow rates beyond safe limits during peak flows, and therefore should not be operated during these periods. This means that controls should be available on the skimming devices so that the rate of skimming can be adjusted or entirely shut off.

TEMPERATURES

All of the CS plants were operated under both summer and winter temperature conditions. There was no significant drop in BOD removals during the coldest periods. One clarifier which was installed above grade had ice forming in the bottom during the early subfreezing periods. Placing straw around the bottom half of the clarifier ended this problem for the remainder

of the winter months. The other above grade plants were also protected in this manner.

MIXED LIQUOR AND STABILIZATION COMPARTMENT SOLIDS

Various levels of solids have been utilized in the contact and stabilization compartments of CS plants. During this study, one plant was operated at a comparatively low solids level in order to maintain a sludge age of three days or a BOD loading of 0.3 lbs. per lb. of aerating solids. The mixed liquor concentration at this loading was approximately 1000 mg per liter. The plant operated satisfactorily in terms of solids removals, but BOD removals were below the solids removals. This would be expected when short contact times or low solids levels prevail.

At the other extreme, a 400,000 GPD CS plant located in Penetanguishene, Ontario,¹¹ is routinely operated with a mixed liquor concentration of 4000 to 7000 mg per liter and a 100 percent return sludge rate. The organic loading on this plant is low with a BOD₅ averaging about 100 mg per liter. BOD removal is approximately 84 percent. Reported performances of other plants in various locations are shown in Table I.

The strength and characteristics of the raw waste, tank capacities, and return sludge rates all affect the solids levels in a contact stabilization plant.

SOLIDS WASTING

Contact stabilization plants require periodic solids wasting. Solids are synthesized at a relatively rapid rate and will accumulate in the system unless a portion of the return sludge is directly wasted from the process, or diverted to an aerobic digester. Long residence periods in the digester will reduce the solids content of the sludge by oxidation and endogenous respiration. This process, however, is slow, and, as a result, some wasting of solids to a drying bed, a holding tank or a tank truck should be anticipated. Solids in the digester can be concentrated by decant thickening, with the supernatant liquor being returned to the stabilization compartment. The thickened sludge can also be discharged from the digester at this time. Continuous return of the supernatant can be achieved by a separator in the digester which provides for overflow of the supernatant back into the stabilization compartment. The digesting sludge which

TABLE I
PERFORMANCE OF CONTACT STABILIZATION PLANTS

Type of Waste and Location Code	BOD ₅ mg/liter	Detention Time, Hours		Suspended Solids, mg/liter		Return Sludge		BOD ₅ Reduction
		Influent	Contact	Stabilization	Contact	Stabilization	Percent	
Municipal Sewage ¹	97		1.5	4.0	7050*	13,000**	100	84.0*
Municipal Sewage ²	358		0.52	5.2	2540	6900**	56	94.1
Municipal Sewage ³	108		1.30	4.25	2239	8629	44	88.0
Municipal Sewage ³	210		0.18	1.00	2500	4500	100	90.0
Sewage and Textile Waste ⁴	225		0.60	5.50	2950	6950	67	77.0
Sewage and Textile Waste ⁴	320		1.10	3.10	3326	7650	68	88.0
Tomato Cannery Waste ⁵	412		0.80	1.60	2250	3600	100	85.0
Tomato and Apple Waste ⁵	492		1.00	2.00	2500	4400	100	89.7
Tomato and Peach Waste ⁵	740		0.65	1.30	3600	5900	100	58.0

*Average Value

**Suspended Solids Estimated from Return Sludge Rate

Location Code:

1. Penatanguishene, Ont.
2. Austin, Texas
3. Little Ferry, N.J.
4. Cone Mills, Greensboro, N.C.
5. Chambersburg, Pa.

Source of Data:

1. Jones, Dr. P. H., "Water and Pollution Control" (Canadian), Feb., 1968, Page 31.
2. Ullrich, A. H. and Smith, Mansel W., "Sewage and Industrial Wastes," Vol. 29, No. 4, (April, 1957), Page 411.
3. Zablatsky, H. R., Cornish, M. D. and Adams, J. K. { "Biological Waste Treatment"
14. Jones, F. L.; Alsap, T. A.; and Stokes, H. B. { Eckenfelder, W. W., Jr. and O'Connor,
15. Eckenfelder, W. W., Jr. and Grich, E. R. { D. J., Pergamon Press, 1961, Page 213.

settles in the separator can then flow by gravity or be pumped back into the digester.¹³

Two of the contact stabilization plants studied had separators installed in the digesters, but separation of the solids into clear supernatant and digested sludge did not always occur. This resulted in some accumulation of solids in the stabilization compartment, since the return sludge which was discharged into the digester would flow back into this compartment. In addition, the separators did not always prevent floatable solids from returning with the supernatant. Manual decanting of supernatant is one method for preventing any solids except those in the supernatant from flowing back. This is accomplished by shutting off the air for approximately two hours, in order to allow the digester liquor to separate into digesting sludge and relatively clear supernatant, which is then decanted.

Records kept on the wasting of sludge from the aerobic digesters indicate that more sludge is produced and not completely oxidized when the solids concentration in the aeration compartments is low. This is due to the fact that the food to microorganism ratio is greater when the active sludge mass or solids concentration is lower, and the net sludge accumulation increases as a result.

CHECK LIST FOR ROUTINE MAINTENANCE AND OPERATION OF CONTACT STABILIZATION PACKAGE SEWAGE TREATMENT PLANTS

1. Determine that power is being supplied to the unit and that all pumps and motors are operating or operational as required.
2. Grease and oil equipment, clean air filters, check pressure relief valves, and perform related work as recommended by the manufacturer.
3. Hose down walkways, sideboards, and splash-spray zones as needed.
4. Check air lifts and return lines for clogging.
5. Operate skimming device(s) as needed.
6. Perform recommended simple laboratory analytical procedures and adjust operating variables as indicated. The recommended or required analytical procedures for a given plant may include, but are not necessarily limited to, any or all of the following depending on the requirements of the particular regulatory agency having jurisdiction and the needs of the installation:
 - a. Influent, effluent, mixed liquor, stabilization compartment, return sludge, and digester suspended and volatile suspended solids. (Rapid photometric methods for the determination of suspended solids have been found to be reliable.)
 - b. Influent and effluent five day biochemical oxygen demand.
 - c. Mixed liquor, stabilization compartment, digester, and effluent dissolved oxygen concentration.
 - d. Influent, mixed liquor, stabilization compartment, digester, and effluent pH and temperature values.
 - e. Mixed liquor, stabilization compartment, and digester thirty minute settled volume determinations (SV₃₀).
7. If effluent disinfection is required, insure that an adequate supply of disinfectant is available and that the feed device is operating properly.
8. Scrape down the insides of clarifier hopper at least daily.
9. Remove litter from the plant area and perform grounds keeping operations as required.
10. Repaint exposed painted surfaces as needed.
11. Inspect aeration equipment thoroughly including diffusers, impellers, and the like which may be submerged. While this may not need to be done as frequently as some other items of maintenance, it should not be overlooked and the manufacturer's recommendations should be carefully followed.
12. Remove and dispose of, in a sanitary manner, any material that may accumulate on inlet bar screens and the like. Check and clean the comminutor if one is a part of the plant.
13. Check, clean, and maintain any such plant support units such as a sand bed, sludge holding tank, trash trap, and the like.
14. Replace worn parts or equipment as needed. Pay particular attention to pulley belts and the like which may require relatively frequent replacement. Maintain a small stock of such items including belts, fuses, heaters, and similar items which are essential to plant operation.
15. Maintain recommended solids level in stabilization compartment for any given return sludge rate by wasting a portion of return sludge to digester.

13. Waste solids from the system as required to maintain the solids within the desired range.

It should be emphasized that daily and conscientious maintenance and operational attention is required in order to achieve the certified level of performance.

III. PERFORMANCE CRITERIA AND THE STANDARD PERFORMANCE EVALUATION METHOD

The findings detailed in Section II have been translated into performance evaluation criteria for contact stabilization package sewage treatment plants. These criteria are as follows:

1. The plant shall display a sustained contact and stabilization suspended solids buildup during the startup period.
2. The plant, when its design loading is not exceeded, shall achieve a sustained design BOD₅ removal after the process reaches maturity.
3. The aeration system shall be capable of transferring sufficient oxygen to meet peak design loads in addition to any other demands made on the system such as maintaining the contents of all aeration compartments completely in suspension, the operation of the air lifts, and the like.
4. The aeration system, when operating at the midpoint of its rated capacity, shall have such flexibility or admit of such adjustment as not to affect adversely the process efficiency.
5. The solids separation system shall be capable of separating and retaining within the plant sufficient solids so as not to affect adversely the over-all process efficiency.
6. The floatable solids retention and skimming system of the solids separation compartment shall be capable of retaining and returning to the aeration compartments sufficient floatables in such a way as not to affect adversely the over-all process efficiency.
7. When subjected to cold weather operating conditions after reaching process maturity, the plant shall achieve essentially the same degree of process efficiency as at other times of the year providing that it and its process support equipment are protected from freezing.

Most of the routine chemical and physical determinations in this study were carried out in accordance with the provisions of the 12th Edition of *Standard Methods for the Examination of Waste and Wastewater*.¹⁴

8. The plant shall have such flexibility as to permit ready maintenance of the desired range of suspended solids under aeration.

Based on the fundamentals of the processes involved, the findings of these studies, the investigations of others as cited, and the performance criteria developed, the following method for the evaluation of the performance of contact stabilization package sewage treatment plants has been devised:

A. PREQUALIFICATION

1. Prior to the performance evaluation of any contact stabilization package sewage treatment plant, the manufacturer of such plant shall supply to the testing agency, group, or organization sufficient evidence to establish to the satisfaction of such agency, group, or organization the basic feasibility of the plant with respect to its intended service.
2. As a part of his application for performance evaluation of a particular plant model or model series, the manufacturer shall set forth the basic description of the plant and design data including complete drawings and specifications for the plant and all of its equipment and appurtenances. The application shall be accompanied by a complete installation, operation, and maintenance manual which includes a thorough discussion of the process fundamentals involved.

B. GENERAL TEST CONDITIONS AND REPORTING

1. The waste utilized as feed for the unit during these evaluations shall be a comminuted domestic waste free of any

industrial waste which in any way might affect the performance of the plant being tested. Stale or septic sewage shall not be utilized. The sewage utilized as feed for the plant shall be sampled **daily* during the test period. The samples shall be twenty-four hour samples composited strictly according to the plant influent flow pattern in use at the time of sampling. Analysis of these samples must establish that the characteristics of the waste utilized as feed during the test conformed to the following:

- a. Five day biochemical oxygen demand (BOD₅) - a mean concentration based on all data of 200 mg per liter plus or minus 30 percent, provided further that none of the samples yield a BOD₅ value of less than 50 mg per liter or more than 400 mg per liter.
 - b. Suspended solids (SS) - a mean concentration based on all data of 220 mg per liter plus or minus 30 percent, provided further that none of the samples yield an SS value of less than 55 mg per liter or more than 440 mg per liter.
 - c. Percent volatile suspended solids - no values less than 65 or more than 85 percent.
 - d. Temperature - no values less than 10 degrees or more than twenty-five degrees Centigrade.
 - e. pH - no values less than pH 6.0 or greater than pH 8.0.
2. All samples shall be strictly taken and preserved as provided in the latest edition of *Standard Methods for the Examination of Water and Wastewater*¹⁴ except as may be otherwise provided herein.
 3. All analytical methods employed shall be those set forth in the latest edition of *Standard Methods*¹⁴ except as may be otherwise provided herein.
 4. During the test period the plant shall be operated and maintained according to the manufacturer's instructions except as these may in any way be in conflict with the provisions of the Standard Performance Evaluation Method in which case the pro-

visions of the Method shall be complied with.

5. The Standard Evaluation Method can be carried out at any time of the year provided that:
 - a. The plant being tested has reached process maturity as defined in 7a. before the solids under aeration fall to 8.0° C.
 - b. During the test period the temperature at no time falls below 5.0° C.
 - c. The plant and its equipment is protected from freezing, if the test is conducted during cold weather.
 - d. The temperature of the aerator contents at no time exceeds 30.0° C, if the test is conducted during warm weather.
6. The performance evaluation of a plant shall be independent of its design and construction except that structural weakness or defects and failures of its process support equipment noted during the test shall be reported as a part of the test results.
7. The Standard Performance Evaluation Method shall consist of two main parts:
 - a. Startup Performance Evaluation: the period between actual startup of the plant and its achievement of a MLSS concentration value designated by the manufacturer. The stabilization compartment suspended solids concentration and the return sludge SS concentration must be adequate to sustain the MLSS minimum under the variable flow pattern as defined in this report.
 - b. Variable Flow Pattern Performance Evaluation: a period of 18 consecutive weeks on a 5 day per week basis beginning with the plant's achievement of the MLSS levels as defined in 7a., plus any other conditions set forth in Paragraph 7.
 - c. During the variable flow period, the MLSS concentration will be adjusted to the range recommended by the manufacturer, plus or minus 20 percent. The plant will be hydraulically loaded at its rated daily capacity and in accordance

¹⁴The term *daily* shall refer to Sunday through Thursday. During the performance evaluation of each plant, additional composite samples of the influent and effluent shall be taken on Friday and Saturday, but analyzed only for BOD₅ and suspended solids.

with an increased or decreased hourly flow rate as outlined in Section F. The rate of return sludge from the settling compartment to the stabilization compartment shall be in accordance with the manufacturer's recommended rates, plus or minus 10 percent. The wasting of return sludge to the digester and the digested sludge from the digester shall be carried out at a rate that will maintain the range of solids required in the contact and stabilization tanks.

8. The information and data developed during each phase will be reported and summarized separately in the certified performance evaluation report.
9. The certified performance evaluation report shall be signed by the chief corporate officer of the testing organization and by the official of the organization in responsible charge of the evaluation. The report shall contain but not necessarily be strictly limited to the following:
 - a. All data and information developed in detail during the evaluation. This information and data shall be grouped according to the two main parts of the evaluation and used only in the calculation of the results of section to which the data pertains. Probability plots for SS, BOD₅, and COD shall be included.
 - b. A certification statement signed by the testing organization officers specified above which states that the Standard Performance Evaluation Method was used in the testing of the plant, that no deviations from this method were made during the test, and that the results reported are true to the best of his information and belief.

C. STARTUP PERFORMANCE EVALUATION

1. The plant shall be completely assembled according to the manufacturer's directions and all of its equipment checked to determine that it is free of mechanical defects and operable. The plant shall be examined to determine that it is structurally sound. All defects noted shall be reported. If no defects are detected this fact shall be reported.
2. If no defects are detected and the plant is judged to be structurally sound, it shall be filled with domestic waste (previously

defined under B-1) as rapidly as possible and immediately placed into full operation. Sampling and testing shall begin as soon as the plant is filled and placed into operation and shall continue until the end of the two parts of the Standard Performance Evaluation Method.

3. Aerator contents residual dissolved oxygen levels shall be maintained between 1.0 and 3.0 mg per liter as nearly as possible. In no case shall the residual dissolved oxygen level be permitted to fall below 0.5 mg per liter except in the immediate vicinity of raw waste introduction. In the event these minimum dissolved oxygen levels cannot be maintained, the test shall be suspended until corrective measures are taken.
4. The raw domestic waste utilized as feed for the unit shall have been passed through a 1/4 inch slot comminutor prior to entering the unit. During this phase of the test it shall be applied in a variable flow pattern as defined elsewhere in this method.
5. Daily twenty-four hour influent and effluent samples composited strictly according to the influent flow pattern shall be collected. The frequency of sampling to make up the required composites shall be at least once hourly.
6. The rate of flow applied to the unit under test shall be measured and recorded continuously and the volume of waste applied daily shall be totaled and reported. The total volume of waste applied to the unit daily shall be the rated capacity of the unit, plus or minus five percent.
7. The daily influent and effluent composites shall be subjected to laboratory analysis (except as noted in Section B-1) to determine the following:
 - a. Five day biochemical oxygen demand (mg/l).
 - b. Suspended and volatile suspended solids (mg/l).
 - c. pH.

The temperature of the influent and effluent shall be determined at maximum flow period and at 8:00 a.m.
8. At the midpoint of the maximum flow period a grab sample of the mixed liquor, digester and stabilization compartment contents shall be taken as near the center of each aeration compartment as possible.

A return sludge grab sample shall be taken at the same time, if possible. Also, at the same time, the dissolved oxygen content and temperature of the contact aeration compartment contents in the immediate vicinity of the raw waste introduction point, and the immediate vicinity of the compartment exit, shall be determined. Also, a dissolved oxygen content and temperature shall be taken at the center of the stabilization compartment and digester. The mixed liquor, stabilization compartment, digester, and return sludge samples shall be subjected to laboratory analysis to determine the following:

- a. Suspended and volatile suspended solids (mg/l)
- b. pH.
- c. Thirty minute settled volume (SV₃₀, ml.). (Sludge volume index computed for mixed liquor samples only.)
9. As soon as the mixed liquor suspended solids concentration reaches the level recommended by the manufacturer, plus or minus 20 percent, the startup evaluation shall be terminated and the variable flow pattern evaluation shall start at once without any interruption of feed to the unit or lapse of time.

D. VARIABLE FLOW PATTERN PERFORMANCE EVALUATION

1. The provisions of Section C, subsections 3, 4, 5, 6, and 8 shall be complied with during this phase of the evaluation.
2. The period of variable flow pattern performance evaluation shall be the next consecutive 18 - 5 day weeks following the startup performance evaluation period.
3. The daily influent and effluent composite samples (see B-1 and C-5) shall be subjected to laboratory analysis to determine the following:
 - a. Five day biochemical oxygen demand (mg/l, BOD₅).
 - b. Suspended and volatile suspended solids (mg/l).
 - c. pH.
 - d. Methyl orange alkalinity (mg/l).
 - e. Ammonia-nitrogen (mg/l, NH₃-N).
 - f. Total phosphate (mg/l-P).
 - g. Chemical oxygen demand (mg/l, COD).

In addition to the above, the daily effluent composite shall also be subjected to the following analyses:

- h. Nitrate-nitrogen (mg/l, NO₃-N).
- i. Nitrite-nitrogen (mg/l, NO₂-N).
- j. Dissolved oxygen (mg/l).

The following analyses shall be made on the influent composite two times per week:

- k. Nitrate-nitrogen (mg/l, NO₃-N).
- l. Nitrate-nitrogen (mg/l, NO₂-N).
4. The temperature of the plant influent and the effluent shall be determined during both the maximum flow period and at 8:00 a.m.
5. The digester shall be sampled in accordance with Section C-8 and the following determinations or analyses made:
 - a. Return sludge wasted to digester (gals.).
 - b. Digested sludge wasted from the digester (gals.).
 - c. Supernatant when wasted from the system (gals.).
 - d. BOD₅ (mg/l) of supernatant when wasted from the system.
 - e. Suspended solids and volatile suspended solids (mg/l) in:
 1. Return sludge
 2. Wasted digester sludge
 3. Supernatant from digester when wasted from system
 - f. SV₃₀ of digesting sludge (two times per week)
 - g. Total phosphates (mg/l-P) in wasted digester sludge or in supernatant wasted from system.
 - h. Dissolved oxygen (mg/l) and temperature (°C) in digester as specified in Section C-8.

E. DEVIATIONS FROM STANDARD METHODS

The following deviations from the procedures described in *Standard Methods for the Examination of Water and Wastewater*¹⁴ may be used for suspended solids determinations:

1. Glass fiber filter mats may be used in place of asbestos in a Gooch crucible.
2. Spectrophotometric measurements may be used.

F. FLOW PATTERNS

When the variable flow pattern is in effect, the percentage of the total daily flow applied during each hour of the day shall be as follows:

Hour	Variable Flow Pattern
12:00M - 1:00AM	1.5
1:00AM - 2:00AM	1.5
2:00AM - 3:00AM	1.5
3:00AM - 4:00AM	1.5
4:00AM - 5:00AM	2.5
5:00AM - 6:00AM	2.5
6:00AM - 7:00AM	3.0
7:00AM - 8:00AM	3.0
8:00AM - 9:00AM	4.0

Hour	Variable Flow Pattern
9:00AM - 10:00AM	4.5
10:00AM - 11:00AM	6.5
11:00AM - 12:00N	6.5
12:00N - 1:00PM	6.5
1:00PM - 2:00PM	6.5
2:00PM - 3:00PM	4.5
3:00PM - 4:00PM	4.5
4:00PM - 5:00PM	4.5
5:00PM - 6:00PM	4.5
6:00PM - 7:00PM	5.0
7:00PM - 8:00PM	5.0
8:00PM - 9:00PM	5.0
9:00PM - 10:00PM	5.5
10:00PM - 11:00PM	5.0
11:00PM - 12:00M	5.0

IV. RESPONSIBILITIES

The proper use and performance of a package sewage treatment plant is dependent on the many parties that are to be involved in its design, manufacture, application, operation, and supervision. The responsibilities of each person, agency, or organization were outlined in the National Sanitation Foundation report on Extended Aeration Sewage Treatment Plants¹ and are repeated in this report with the modifications necessary for the contact stabilization process.

A. THE MANUFACTURER-SUPPLIER

1. It is the responsibility of those who manufacture and supply package sewage treatment plants to insure the durability and workability of the plant's structure and process support equipment. It is further their responsibility to guarantee such durability and workability to the buyer-owner.
2. It is the responsibility of the manufacturer-supplier to define and warrant the overall process efficiency to be expected in connection with the treatment of a stated waste having specified characteristics, excepting that such warranty is valid only so long as the responsibilities of the other parties are met by them.
3. The manufacturer-supplier should provide the services of a qualified technician who is thoroughly knowledgeable concerning the equipment and processes involved to assist the installation of the plant, supervise the startup of the plant, and instruct the buyer-owner's operator in the

proper operation and maintenance of the plant. Such a qualified individual should also be supplied for a recheck of the plant after the mixed liquor suspended solids concentration recommended by the manufacturer has been achieved to insure that the plant is operating properly, and to further instruct the buyer-owner's operator. Technical service in addition to the above should also be provided at the owner's request and at his expense, except as any guarantee or warranty between the parties may apply.

4. If the plant is installed by the manufacturer-supplier he should guarantee such installation. If the plant is installed by other than the manufacturer-supplier he should supply the installer with adequate installation instructions.
5. The manufacturer-supplier should provide the buyer-owner at the time of plant startup with a complete manual outlining the proper operation and maintenance procedures including adequate drawings and descriptive literature so as to render these matters understandable to a qualified operator of such plants. This manual should also include a complete but readily understood discussion of the principles involved in the processes employed by the plant, as well as a thorough description and discussion of the test methods required for the intelligent operation of such processes.
6. Also at the time of startup of the plant, the manufacturer should supply the owner

with a complete replacement parts list for the plant and all of its equipment including up-to-date information on the availability of replacement parts, parts suppliers, and any known applicable substitute parts. Further, such parts list should contain a recommendation concerning the types and quantities of spare parts which the buyer-owner should maintain on hand to facilitate emergency repairs. Any unusual tools that might be required for the proper repair or maintenance of the plant and its equipment should also be brought to the owner's attention by suitable mention in the parts list or maintenance manual. The availability of replacement parts for a specified period of time should be a part of the manufacturer-supplier's warranty to the buyer-owner.

7. It should be the responsibility of the manufacturer-supplier to furnish certified copies of the Standard Performance Evaluation Method results available pertaining to the particular plant model series involved as a part of any submission of plans and specifications to a reviewing regulatory agency or official that may be required by law or regulation. It should be his further responsibility to provide the same information to the buyer-owner and his engineering consultant.

B. THE BUYER-OWNER

1. It is the responsibility of those who buy, own, and operate package sewage treatment plants to secure or provide the services of a competent engineer to set up specified critical flow ranges and loadings for sizing the plant within the general or specific requirements of the regulatory agencies or officials having jurisdiction, to determine plant location, and to perform related engineering services as outlined herein.
2. The owner of a package sewage treatment plant has the responsibility of providing as the plant operator a person who is conscientious, of adequate intelligence, and in good physical condition and who, therefore, is capable of learning to operate and maintain the plant within a reasonably short period of time, given adequate instruction.
3. In the event the original plant operator leaves the employ of the owner it is the owner's responsibility to secure immediately a replacement who has the same

attributes as those set forth for the original operator and to provide the new operator with suitable training for the job.

4. It is the responsibility of the buyer-owner, through his engineering consultant, to secure from the agencies or officials having jurisdiction the approvals, permits, or licenses required by law or regulation for the construction and operation of the plant unless this is specifically delegated by contract to another of the parties.
5. It is also the responsibility of the owner to give general supervision to his operator and to provide the operator with all necessary tools, materials, parts, and the like required for the proper operation and maintenance of the plant. It should be noted in this connection that the owner himself is ultimately responsible for the performance of the plant.
6. The owner of a package sewage treatment plant is responsible for any failure of the plant to perform as set forth in the manufacturer-supplier's warranty or as required by law or regulation when such failure is the result of organic or hydraulic loadings or waste characteristics which differ from those in the warranty. It should be further noted that the owner is, in most jurisdictions, solely responsible for any failure of the plant to perform as required by law or regulation regardless of cause.

C. THE CONSULTING-SUPERVISING ENGINEER

1. The owner's engineer is responsible for the setting of organic and hydraulic load levels to be applied to the plant, and for selecting the plant(s) which in his best judgment are capable of reliably treating the waste at these loadings in such a manner as to conform with all applicable laws and regulations.
2. Not only is the engineer responsible for defining the load levels to be treated, but he is further responsible for defining both the organic and hydraulic pattern of loading and the specific characteristics of the waste to be treated. It is the additional responsibility of the engineer to disclose fully all of these characteristics, loadings, and conditions to the manufacturer-supplier and the buyer-owner as well as the regulatory agencies and officials having jurisdiction.

3. The engineer is responsible for determining the location of the plant, the design of adequate inlet and outlet sewers, the design of required auxiliary structures and appurtenances as required, as well as necessary power lines and the like.
4. It is ordinarily the responsibility of the engineer to represent the buyer-owner in securing the required permits and licenses or to delegate this by contract or agreement to another of the parties.
5. It is the responsibility of the engineer to oversee generally and to inspect the installation and construction of the plant and its appurtenances specified in the contract drawings, and to require such corrections to be made by the manufacturer-supplier/installer as may be necessary in order to conform to the approved drawings and specifications.

D. THE INSTALLER-CONTRACTOR

1. In the event that an installer-contractor rather than the manufacturer-supplier installs the package sewage treatment plant, it is the responsibility of such installer-contractor to make the installation in accordance with the manufacturer-supplier's instructions.
2. It is the further responsibility of the installer-contractor to insure that good workmanship standards are maintained and that the over-all process efficiency is not limited by any defect in installation.

E. THE REGULATORY AGENCY-OFFICIAL

1. In the course of the normal discharge of their duties, regulatory agencies and officials having jurisdiction should carefully review all of the available information concerning the package sewage treatment plant proposed for use in each particular case. This review should include the Standard Performance Evaluation Method results which pertain to the particular plant model or model series which is being proposed. After such review it should finally be the responsibility of the agency-official to make a value judgment as to the capability of the proposed plant to treat the specific waste, in view of the loadings and loading pattern, to the degree required in each case.
2. Following the installation of the plant, the regulatory agency-official should normally

make an inspection of the plant. The agency-official should require the owner to submit for review certain test results and operating reports and should conduct such tests and inspections as required to insure that the performance of the plant meets the waste treatment requirements in each case.

3. In the event that the agency-official determined that the plant was not meeting the waste treatment requirements, the owner should be required to take the necessary steps to insure the required level of treatment.

F. THE PLANT OPERATOR

1. The plant operator is responsible for the conscientious and proper operation and maintenance of the plant under the over-all responsibility of the owner.
2. It is also the responsibility of the operator to make such observations and to conduct such tests as may be required for the proper operation of the processes involved in the plant, to record the results of such observations and tests, and to make these results known to the owner who, further, may be required to make them known to the regulatory agency-official.
3. The operator has the responsibility of advising the owner as to the tools, supplies, and parts which may be required from time to time for the proper operation and maintenance of the plant and to do so in sufficient time to insure that such items are available when needed.
4. It is a prime responsibility of the operator to become fully acquainted with the plant and all of its appurtenances, especially including the processes involved in the treatment system, and to take full advantage of all training offered by the manufacturer-supplier, owner, and regulatory agency-official.
5. The operator is responsible for informing the owner at once of any process interruptions or observed losses of efficiency of such a nature or extent as to render the waste treatment level less than that required by law or regulation.

G. THE PERFORMANCE EVALUATION ORGANIZATION

1. It is the responsibility of the agency, group, or organization which conducts

plant performance evaluations to do so strictly in accordance with the Standard Performance Evaluation Method and to certify the results of such testing to the manufacturer of the plant. In addition to the detailed test results a data summation shall be supplied.

2. Standard Performance Evaluation Method data should be used by a recognized testing organization in a certification program. Such a program would make standard performance information readily available for use by those concerned in

making judgment decisions regarding package sewage treatment plants.

From the foregoing seven sections on the responsibilities of the various parties concerned in the design, manufacture, testing, use, and supervision of package sewage treatment plants, it is clear that each of these parties influences and contributes to the final over-all plant performance actually observed in the field. In the final analysis, no one of these factors can be said to be truly more important than any other for it requires the best efforts of all concerned to achieve the desired result.

V. DISCUSSION

This report entitled, "Package Sewage Treatment Plants Criteria Development, Part II: Contact Stabilization" completes the three year study conducted by the National Sanitation Foundation on package plants. The first report on Extended Aeration Package Plants¹ was released in September 1966 and contains, in addition to information on the development of criteria for the performance evaluation of extended aeration plants, many details on the test equipment, research site layout, and laboratory procedures. Much of the latter material has been omitted from this report.

Sometime during the contact stabilization phase of this study, the "treatability" characteristics of the raw waste changed. Symptoms of the problem included: (1) production of a layer of tenacious "frothy solids" on the top of aeration chambers; (2) development of sludge particles which settled quite slowly; (3) production of rising sludge in the settling compartment; (4) discharge of a turbid effluent which contained as suspended matter some of the very fine and light unsettled solids or rising sludge. Meticulous operational management of package plants could not prevent these manifestations. During this same period, the new and efficiently operated activated sludge plant serving the City of Ann Arbor was similarly affected, and its process efficiency dropped below the anticipated levels.

The factor(s) causing the upset were not identified, but every effort is being made to prevent its recurrence. During this period the treatment efficiencies of all four contact stabilization plants in the study were comparable with that of the Ann Arbor plant. In 1966 and 1967, the Ann Arbor plant recorded mean reductions in BOD and suspended solids of 88 to 90 percent.

The purpose of this phase of the study was to develop performance criteria for contact stabilization type package sewage treatment plants. It should be emphasized that the data which appears in this report was collected during the period of criteria development and not under necessarily normal operating conditions. In order to establish acceptable minimum and maximum levels of performance, operating parameters were varied somewhat from those described in Section III of this report. No data selection was practiced in preparing Tables II through V. All results are reported.

Operation of these plants indicated that this process can satisfactorily remove the major portion of both suspended solids and the biochemical oxygen demand in domestic wastewater without the creation of an odor or noise nuisance in the surrounding area. The data which was collected did not disclose any variation of performance capability attributable to plant capacity.

VI. ACKNOWLEDGMENTS

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The manufacturers listed below supported the contact stabilization plant criteria development project by providing package treatment plants of this type for the study:

Chicago Pump Co., Hydrodynamics Division
FMC Corporation
Chicago, Illinois

Davco Manufacturing Company
Thomasville, Georgia

Defiance, Incorporated
Tallevast, Florida

Water Pollution Control Corporation
Milwaukee, Wisconsin

The National Sanitation Foundation greatly appreciates the aid that these companies generously gave to the project.

The Foundation acknowledges the cooperation and support of the City of Ann Arbor through its Superintendent of the Ann Arbor Wastewater Treatment Plant, Mr. Richard Sayers. The city provided laboratory and office space for the National Sanitation Foundation's project staff. The untimely death of Mr. C. Preston Witcher, the former Superintendent of the Ann Arbor plant and an advisor to the Technical Committee, occurred in April 1968. The aid that Mr. Witcher gave in the initial stages of the project is deeply appreciated.

The direction that the Technical Committee has given to the contact stabilization plant criteria development project is gratefully acknowledged. The committee's members from industry were chosen from the organizations that provided plants for the study. The committee's membership is listed below:

Mr. Donald M. Pierce, Chairman
Chief, Wastewater Section
Division of Engineering
Michigan Department of Public Health
Lansing, Michigan 48914

Mr. George H. Eagle, Vice Chairman
Chief Engineer
Division of Engineering
Ohio Department of Health
Columbus, Ohio 43216

Mr. Eagle was represented by
Mr. L. T. Hagerty at two meetings of the committee

Mr. Sidney A. Berkowitz
Director
Bureau of Sanitary Engineering
Florida State Board of Health
Jacksonville, Florida 32201

Mr. Richard S. Nelle
Division of Sanitary Engineering
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Mr. Ralph Porges
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Trenton, New Jersey 08603

Mr. R. J. Schliekelman
Director, Water Pollution Division
Iowa State Department of Health
Des Moines, Iowa 50319

Mr. Tom H. Forrest
Director of Technical Sales
Chicago Pump, Hydrodynamics Division
FMC Corporation
Chicago, Illinois 60614

Mr. Forrest was represented by
Mr. Edward Matras at one meeting of the committee

Mr. James B. Hostetler
Engineer
Davco Manufacturing Company
Thomasville, Georgia 31792

Mr. Paul M. Thayer
Vice President - Engineering
Water Pollution Control Corporation
Milwaukee, Wisconsin 53201

Mr. Thayer was represented by
Mr. Frank Schmit at two meetings of the committee

The Executive Committee, the Policy Committee, and the Industry Committee are listed in the first report.¹ Their membership is essentially unchanged. Acknowledgment of their continuing guidance to this portion of the study is also made.

The National Sanitation Foundation's project staff should be cited for their extreme devotion and efforts in making the project function successfully.

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TABLE II *

FALL AND WINTER STUDIES

CONTACT STABILIZATION PACKAGE SEWAGE TREATMENT PLANTS

FULL DESIGN LOADING - STEADY STATE FLOW PATTERN

Item	No. of Samples	INFLUENT			No. of Samples	EFFLUENT			Percent Removal
		Min.	Max.	Mean		Min.	Max.	Mean	
BOD ₅ (mg/l)	415	64	344	167	408	1.0	320	33	80.2
SS (mg/l)	425	94	534	192	426	2.0	304	47	75.5
VSS (mg/l)	425	80	504	158	425	1.0	300	30	81.0
MBAS (mg/l)	312	2.0	9.8	5.2	312	0.3	5.3	1.4	73.1
COD (mg/l)	387	59	490	286	387	5.0	320	74	74.1
NH ₃ - N (mg/l)	388	4.0	40	12.8	388	0.0	23	6.2	
NO ₃ - N (mg/l)	394			***	394	0.1	27.8	8.7	
PO ₄ - P (mg/l)	382	8.8	135	55.2	382	8.0	55.6	22.9	58.5

MIXED LIQUOR AND STABILIZATION COMPARTMENT SOLIDS

Item	Samples	Min.	Max.	Mean	Percent Volatile
MLSS (mg/l)	428	80	6170	2385	72.3
MLVSS (mg/l)	417	60	5350	1942	
SV ₃₀ (ml)	410	10	990	572	
SVI	410	17	738	213	79.6
SCSS (mg/l)	210	21	9870	3551	
SCVSS (mg/l)	209	17	7830	2827	
RSSS (mg/l)	422	40	10,400	4694	77.0**
RSVSS (mg/l)	216	30	7880	3534	

*These data were collected during the period of criteria development and are not the result of testing under the conditions established for certification testing.

**Calculated from paired samples only.

***The mean NO₃ - N in the influent for this series of data was 0.5 mg/l.

TABLE III *

SPRING AND SUMMER STUDIES

CONTACT STABILIZATION PACKAGE SEWAGE TREATMENT PLANTS

FULL DESIGN LOADING - STEADY STATE FLOW PATTERN

Item	INFLUENT				EFFLUENT				Percent Removal
	No. of Samples	Min.	Max.	Mean	No. of Samples	Min.	Max.	Mean	
BOD ₅ (mg/l)	53	75	320	156	53	4.0	58	23	85.3
SS (mg/l)	53	110	416	179	53	7.0	118	28	84.4
VSS (mg/l)	53	72	346	142	53	5.0	80	19	86.6
MBAS (mg/l)	53	1.5	6.8	4.7	53	0.0	2.8	1.1	76.6
COD (mg/l)	53	60	558	288	53	11	162	61	78.8
NH ₃ - N (mg/l)	40	6.2	18.2	11.1	40	0.8	10.5	4.9	
NO ₃ - N (mg/l)	53			***	53	0.8	21.8	8.9	
PO ₄ - P (mg/l)	40	10	64	27.3	40	9.2	42.0	20.2	26.0

MIXED LIQUOR AND STABILIZATION COMPARTMENT SOLIDS

Item	No. of Samples	Min.	Max.	Mean	Percent Volatile
MLSS (mg/l)	52	268	4170	1498	67.4
MLVSS (mg/l)	52	128	2690	1009	
SV ₃₀ (ml)	50	10	210	108	
SVI	50	24	225	72	
SCSS (mg/l)					
SCVSS (mg/l)					
RSSS (mg/l)	51	440	7930	3143	68.2**
RSVSS (mg/l)	31	730	5080	2415	

*These data were collected during the period of criteria development and are not the result of testing under the conditions established for certification testing.

**Calculated from paired samples only.

***The mean NO₃ - N in the influent for this series of data was 0.6 mg/l.

TABLE IV *

WINTER AND SPRING STUDIES

CONTACT STABILIZATION PACKAGE SEWAGE TREATMENT PLANTS

FULL DESIGN LOADING - VARIABLE FLOW PATTERN

Item	INFLUENT				EFFLUENT				Percent Removal
	No. of Samples	Min.	Max.	Mean	No. of Samples	Min.	Max.	Mean	
BOD ₅ (mg/l)	248	112	305	184	236	6.0	236	46	75.0
SS (mg/l)	252	98	282	171	251	0.0	238	24	86.0
VSS (mg/l)	248	88	234	145	248	0.0	198	19	86.9
COD (mg/l)	244	164	652	369	241	20	272	74	79.9
NH ₃ - N (mg/l)	124	10.0	25.0	18.5	124	1.0	20	10.6	
NH ₃ - N (mg/l)	128			***	128	0.2	20.2	4.5	
PO ₄ - P (mg/l)	120	22.0	72.0	37.2	120	12	40.8	26.5	28.8

MIXED LIQUOR AND STABILIZATION COMPARTMENT SOLIDS

Item	No. of Samples	Min.	Max.	Mean	Percent Volatile
MLSS (mg/l)	252	660	5260	1942	79.9
MLVSS (mg/l)	249	420	4530	1552	
SV ₃₀ (ml)	248	50	850	343	
SVI	248	41	495	177	80.4**
SCSS (mg/l)	246	600	8010	2924	
SCVSS (mg/l)	125	850	6640	2492	
RSSS (mg/l)	540	1000	8400	3485	81.6**
RSVSS (mg/l)	43	1170	6400	3332	

*These data were collected during the period of criteria development and are not the result of testing under the conditions established for certification testing.

**Calculated from paired samples only.

***The mean NO₃ - N in the influent for this series of data was 0.2 mg/l.

TABLE V *

SPRING AND SUMMER STUDIES

CONTACT STABILIZATION PACKAGE SEWAGE TREATMENT PLANTS

FULL DESIGN LOADING - VARIABLE FLOW PATTERN

Item	No. of Samples	INFLUENT			No. of Samples	EFFLUENT			Percent Removal
		Min.	Max.	Mean		Min.	Max.	Mean	
BOD ₅ (mg/l)	87	100	297	167	86	1.0	220	37	77.8
SS (mg/l)	88	126	344	184	88	3.0	318	45	75.5
VSS (mg/l)	88	70	278	149	88	0.0	218	35	76.5
MBAS (mg/l)	83	1.9	10	5.6	83	0.0	2.4	0.6	89.3
COD (mg/l)	88	140	676	368	88	16	392	89	75.8
NH ₃ - N (mg/l)	88	6.0	22.1	17.1	88	3.3	22.1	10.7	
NO ₃ - N (mg/l)	88			**	88	0.3	16.0	3.5	
PO ₄ - P (mg/l)	87	21	80	52.9	87	23.2	53.6	36.3	31.4

MIXED LIQUOR AND STABILIZATION COMPARTMENT SOLIDS

Item	No. of Samples	Min.	Max.	Mean	Percent Volatile
MLSS (mg/l)	91	1300	6650	3406	75.2
MLVSS (mg/l)	91	970	4550	2561	
SV ₃₀ (ml)	91	90	950	531	
SVI	91	39	486	156	76.5
SCSS (mg/l)	68	2970	8460	5572	
SCVSS (mg/l)	68	2270	6840	4264	
RSSS (mg/l)	91	1110	11,580	6935	73.0
RSVSS (mg/l)	91	740	8830	5062	

*These data were collected during the period of criteria development and are not the result of testing under the conditions established for certification testing.

**The mean NO₃ - N in the influent for this series of data was 0.4 mg/l.